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MULTILINE LASER PROTECTION: THE COPPER VAPOR LASER.(U)
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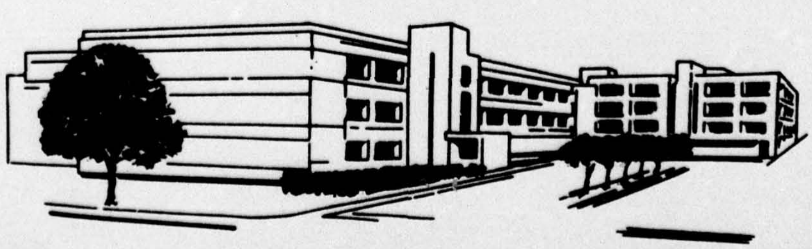
MULTILINE LASER PROTECTION: THE COPPER VAPOR LASER



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The problem of optimizing protection and visibility for a multiline laser, the copper vapor laser (510 and 578 nm), is considered. The effects of three available laser protective materials on the sensitivity of the CIE photopic observer are graphically shown individually and in various combinations. The graphic representation of the effects on the human visibility curves is used rather than the single value, the luminous transmission. Didymium glass plus an argon laser protective material may provide the best protection but has the serious limitation of restriction of sensitivity in the "blue-green" region of

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sensitivity in the "blue-green" region of the spectrum. Development of new laser protective systems as well as new materials for optimizing both protection and visibility are strongly recommended.

ABSTRACT

The problem of optimizing protection and visibility for a multi-line laser, the copper vapor laser (510 and 578 nm), is considered. The effects of three available laser protective materials on the sensitivity of the CIE photopic observer are graphically shown individually and in various combinations. The graphic representation of the effects on the human visibility curves is used rather than the single value, the luminous transmission. Didymium glass plus an argon laser protective material may provide the best protection but has the serious limitation of restriction of sensitivity in the "blue-green" region of the spectrum. Development of new laser protective systems as well as new materials for optimizing both protection and visibility are strongly recommended.

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INTRODUCTION

The protection of the eye against laser radiation must provide optimum absorption of the laser wavelength without significant impairment of the vision of the user. The optical density required to protect at a given laser wavelength can be obtained from appropriate standards depending on the operating conditions of the laser. A measure of the ability to "see" through an absorber is given by the luminous transmission. Although the minimum luminous transmission has been established, this value does not characterize the specific spectral losses in visual sensitivity produced by the use of the laser protective materials.

The Copper Vapor Laser, currently being tested for military applications, poses a problem of multiline protection.[3] The wavelengths of light emitted by this laser are at 510.5 and 578.2 nm. These wavelengths are essentially at the peaks of the relative CIE photopic and scotopic luminous efficiency functions.[4] The luminous efficiency functions are the relative sensitivities of the standard CIE photopic and scotopic observer (Appendix A). The relationship of these laser lines to the maximal sensitivities of the scotopic and photopic systems makes the task of optimizing visual protection and visual sensitivity extremely difficult.

The purpose of this paper is to analyze this problem and to suggest some reasonable first approximations to its solution.

MATERIALS AND METHODS

The sensitivity of the standard CIE photopic observer[4] was weighted for the absorption of three laser protective materials; ruby laser protective goggle (American Optical Corp., Southbridge, MA), argon laser protective goggle (Glendale Optical Co., Woodbury, NY), and a didymium filter (A. H. Thomas Co., Philadelphia, PA) (Appendix B). All are commercially available. The effects of these materials, in various combinations, to both protect and provide optimal visibility were also determined. All data were graphically displayed by a plotting routine written for a PDP-12 computer (Digital Equipment Corp., Maynard, MA).

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[1]Holst, G. C., Am J Optom, 50:477, 1973.

[2]Holst, G. C., Frankford Arsenal Report No. FA-TR-76021, 1976.

[3]Stuck, B. E., Telephone or Verbal Conversation Record, 1977.

[4]Wyszecki, G., et al., Color Science Concepts and Methods, Quantitative Data and Formulas, 1967.

RESULTS

In Figure 1 the relative sensitivities of the standard CIE photopic and scotopic observers are shown with the vertical lines indicating the principal emission wavelengths of the copper vapor laser. The emission lines of this laser intersect the sensitivity of the photopic and scotopic observers at or very near their maxima. In order to protect at these wavelengths, the maximal sensitivities of the photopic and scotopic systems must be attenuated. The trade-off between protection and visibility (sensitivity) is difficult to optimize.

In Figures 2a to 2c the independent effects of each material on photopic visibility are shown. The ruby laser protective material reduces the sensitivity of the photopic observer only slightly (about 60%) up to about 540 nm (Figure 2a). Above 540 nm the sensitivity drops off very sharply. At 640 nm and above this material reduces the sensitivity of the normal photopic observer by a factor of 100. For such a goggle, "red" lights and signs appear "black" and subtle contrast differences between red objects may very likely go unnoticed.

The argon laser protective material reduces the sensitivity of the photopic observer in the "blue-green" region of the spectrum (Figure 2b). No effect is observed in the long wavelength region beyond 560-580 nm. Below this region a very sharp reduction in visual sensitivity occurs. At 540 nm the sensitivity of the photopic observer is attenuated by as much as 1000. Unlike the ruby laser protective material, the argon laser protective material reduces the visibility of "blue or green" objects.

The effect of the didymium filter alone is relatively minor on the photopic observer. A change in sensitivity at 580 nm is the effect of this material on the sensitivity of the photopic observer (Figure 2c).

The effects on the sensitivity of the photopic observer of three combinations of the above materials are shown in Figure 3. Combination of the ruby and argon laser protective materials severely restricts the spectral range of the photopic observer (Figure 3a). Beyond 640 nm, the sensitivity of the photopic observer is reduced by at least 100 and for wavelengths below 540 nm the reduction is at least 1000. Between 560 and 580 nm the sensitivity is decreased by a factor of 10.

The combinations of the ruby laser protective material plus the didymium filter and argon laser protective material plus the didymium filter are shown in Figures 3b and 3c. The ruby laser protective material plus the didymium filter minimally reduce sensitivity up to 540 nm. Sensitivity at 640 nm is at least 100 times lower than the normal photopic observer. For the argon laser protective material plus

the didymium filter, the region of the spectrum below 540 nm is depressed by at least 1000 times. At 580 nm the sensitivity is reduced by a factor of 10. No change in sensitivity beyond 620 nm is produced by this combination.

DISCUSSION

Of the three combinations we have shown in Figure 3, the didymium filter plus the argon laser protective material affords the best protection against the ocular hazard of exposure to the copper vapor laser. The 510 nm line of this source is three times more intense than the 578 nm line, therefore, protection should be greater in the "blue-green" region. On the other hand, visibility in the "blue-green" region of the spectrum is severely limited by this combination. The didymium filter plus the ruby laser protective material combination affords less protection in the "blue-green" region but more visibility. Protection in the region of the spectrum where the hazard is greatest, however, is minimal.

The effects of reducing visibility in the "blue-green" region of the spectrum needs to be elaborated. These effects are extensive as they affect <u>both</u> photopic and scotopic vision. Normal color vision will be significantly reduced producing large changes in color discrimination.[5] Some very recent information[6] suggests that prolonged use of spectrally tinted glass may produce permanent alterations in normal color vision. Similarly, scotopic vision or night vision will be affected, at least temporarily, as the maximum sensitivity of the dark adapted human eye is at 510 nm. No information is available on the possible long-term effects of prolonged use on scotopic visual function.

CONCLUSIONS

The combination of a didymium filter plus the argon laser protective material is adequate to meet immediate protection needs required for the multiline copper vapor laser. Photopic visibility is, however, severely restricted in the "blue-green" region of the spectrum. New materials and concepts are required for development of multiline laser protective devices that optimize visibility and provide maximum protection.

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[5]Le Grand, Y., Handbook of Sensory Physiology, Vol. IV, pp 413, 1972.

[6]Hill, A. R., et al., <u>Mod Prob Ophthalmol</u>, 17:264, 1976.

RECOMMENDATIONS

The effects of laser protective materials on the sensitivities of standard CIE photopic observer demonstrate the need to characterize these effects in a new manner. In this paper, we have presented the effects on photopic visibility in a manner that is graphic. From this type of representation one can easily understand the problem of characterizing visibility through laser protective materials as a single value -- the luminous tranmission. Laser protective materials are designed to be highly "opaque" in a particular region of the spectrum, and as current materials are rather broadbanded, the end result is a considerable selective spectral restriction on the visibility curves. A luminous transmission of 35% may be acceptable but one should understand that this value is a "total" and, therefore, could be misleading when visibility through highly selective spectral material is involved.

Both the argon and ruby laser materials have values of luminous transmission of about 35%, yet they severely restrict the photopic observer in the "blue-green" and "red" regions of the visible spectrum, respectively. The problem of protecting against multiline lasers in the visible compounds this problem and "illuminates" the need to develop new materials and concepts that maximize both protection and visibility. The combination presented here of a didymium filter plus the argon laser protective material is adequate to meet immediate protection needs but is far from adequate in terms of visibility.

The concept of a "dynamic filter" whose transmission is selective and dependent upon intensity and wavelength input should be investigated as an alternative solution to the problem. Such filters are currently used to protect pilots from the intense broadbanded light associated with nuclear flashes.[7,8] Some modifications to existing or prototype systems may be possible so that very selective spectral protection could be provided, only briefly interrupting normal visibility. This is a concept we feel may well be worth some effort.

The ability of different biological systems to uniquely adapt to the photic and spectral input of their environments needs to be examined for possible new protective concepts. The manner in which

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[7]Department of the Navy Aerospace Medical Research Department Report No. NADC-MR-6609, 1966.

[8]CHISUM, G. T., et al., Naval Air Development Center Report No. NADC-72175-CS, 1977.

biological systems have adapted to their own peculiar photic environments may provide important concepts in designing new protective devices. The roles of some known protective mechanisms such as adaptation, blink reflex, and pupillary reaction needs to be investigated.

REFERENCES

1. HOLST, G. C. Proper selection and testing of laser protective materials. Am J Optom, 50:477, 1973.

2. HOLST, G. C. Reduction of target detectability by laser materials. Report No. FA-TR-76021. Philadelphia: Frankford Arsenal, 1976.

3. STUCK, B. E. Protective goggles for a copper vapor laser. A copper vapor laser emits at 510.5 and 578.2 nm simultaneously with an average output power of 6 watts approximately 75% of the total power is emitted at 510.5 nm. The pulse repetition frequency is about 6 KHz with single pulses of 10 to 30 nsec in duration. For this particular laser it is reasonable to assume that this device can operate continuously for hours at a time. Telephone or Verbal Conversation Record, 10 February 1977.

4. WYSZECKI, G., and W. S. STILES. Color Science Concepts and Methods, Quantitative Data and Formulas. New York: John Wiley and Sons, Inc.. 1967.

5. LE GRAND. Y. Spectral luminosity. Handbook of Sensory Physiology. Volume IV, pp 413. Berlin: Springer-Verlag, 1972.

6. HILL, A. R., and R. W. W. STEVENSON. Long-term adaptation to ophthalmic tinted lenses. Mod Prob Ophthalmol, 17:264. 1976.

7. DEPARTMENT OF THE NAVY. AEROSPACE MEDICAL RESEARCH DEPARTMENT. Development of Improved Eye Protection Goggles. Report No. NADC-MR-6609. Warminster: Naval Air Development Center, Johnsville. 1966.

8. CHISUM, G. T., and B. S. MORWAY. SY116-B photochromic flashblindness protection system evaluation. Report No. NADC-72175-CS. Warminster: Naval Air Development Center. Johnsville, 1977.

APPENDIX A

The relative photopic luminous efficiency function (V_λ) gives the ratio of the radiant flux (watts) at wavelength λ_m (Φ_{λ_m}) to that at wavelength λ (Φ_λ) when the two fluxes produce the same photopic luminous sensations under specified photometric conditions.[4] The value of λ_m is chosen so that the maximum value of the function is unity (i.e., the function is normalized). Symbolically, the function has the form given in Equation #1.

$$V_\lambda = \frac{\Phi_{\lambda m}}{\Phi_\lambda} = \frac{1}{\Phi_\lambda / \Phi_{\lambda_m}} \qquad \#1$$

This function is simply the normalized photopic spectral sensitivity function. The lower the value of V_λ, the larger the flux Φ_λ required to evoke a photopic luminous sensation equal to that produced by Φ_{λ_m} (i.e., the system is less sensative at λ than at λ_m). V_λ is defined for photopic or light adapted conditions. The definition for scotopic or dark adapted conditions is completely analogous. The International Commission on Illumination (CIE) has standardized this function on the basis of "normal" visual function of the average observer for both photopic and scotopic conditions. This function is commonly referred to as the sensitivity of the standard CIE observer.

APPENDIX B

Consider the placement of an absorber with transmission T_λ at wavelength λ in front of the eye. Let Φ_λ^I be the flux incident upon the absorber required to produce the same visual sensation as Φ_{λ_m} (Appendix A) incident upon the eye alone. The sensitivity S_λ of the visual system with the absorber is given by Equation #2.

$$S_\lambda = \frac{1}{\Phi_\lambda^I / \Phi_{\lambda_m}} \qquad \#2$$

The flux Φ_λ incident upon the eye in this case is given by Equation #3.

$$\Phi_\lambda = T_\lambda \Phi_\lambda^I \qquad \#3$$

Consequently, Equation #2 becomes:

$$S_\lambda = \frac{1}{\Phi_\lambda / T_\lambda \Phi_{\lambda_m}} = T_\lambda V_\lambda \qquad \#4$$

The luminous efficiency function V_λ is the same as defined in Appendix A. The logarithm (base 10) of the sensitivity is given by Equation #5.

$$\log S_\lambda = \log (T_\lambda V_\lambda) = -(\log \frac{1}{V_\lambda} + \log \frac{1}{T_\lambda}) \qquad \#5$$

However, log $\frac{1}{T_\lambda}$ is simply the optical density (OD) of the absorber at wavelength λ. The log relative sensitivity (LRS) was plotted in this paper by adding an arbitrary value of 5 to both sides of Equation #6 for the convenience of having a positive axis.

$$LRS = 5 + \log S = 5 - (\log \frac{1}{V_\lambda} + OD_\lambda) \quad \#5$$

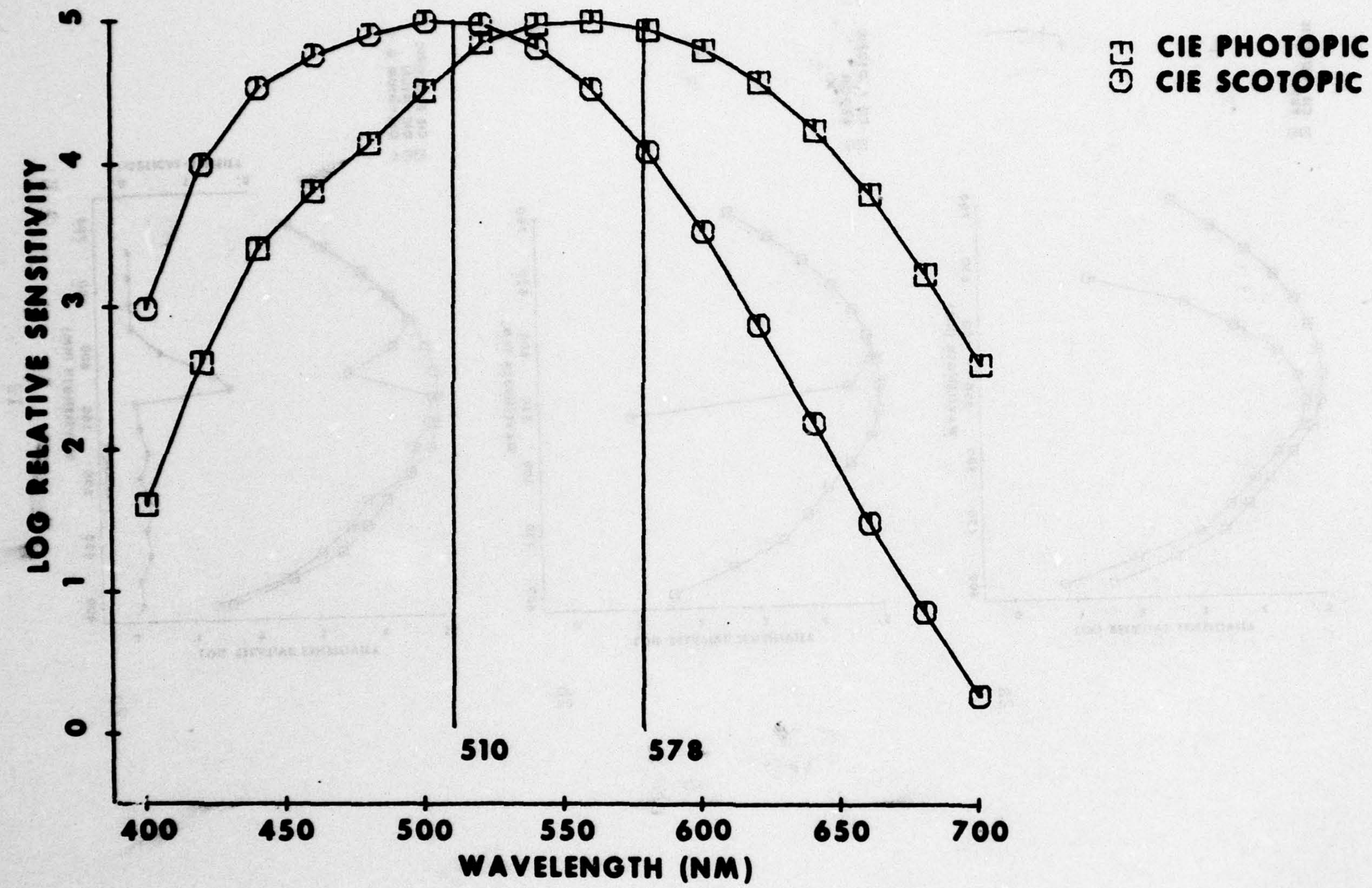
APPENDIX C

Figure 1 The sensitivities of the CIE photopic and scotopic observers relative to the 510 and 578 nm lines of the copper vapor laser. Both curves are normalized with respect to their maxima.

Figure 2 The effects of each of three laser protective materials on the sensitivity of the CIE photopic observer are shown. The ruby laser protective material severely restricts the photopic observer above 540 nm whereas the argon laser protective material severely restricts this function below 540 nm. The didymium filter reduces sensitivity maximally at 580 nm by a factor of 10 as well as producing overall decrease in sensitivity from 560 to 620 nm.

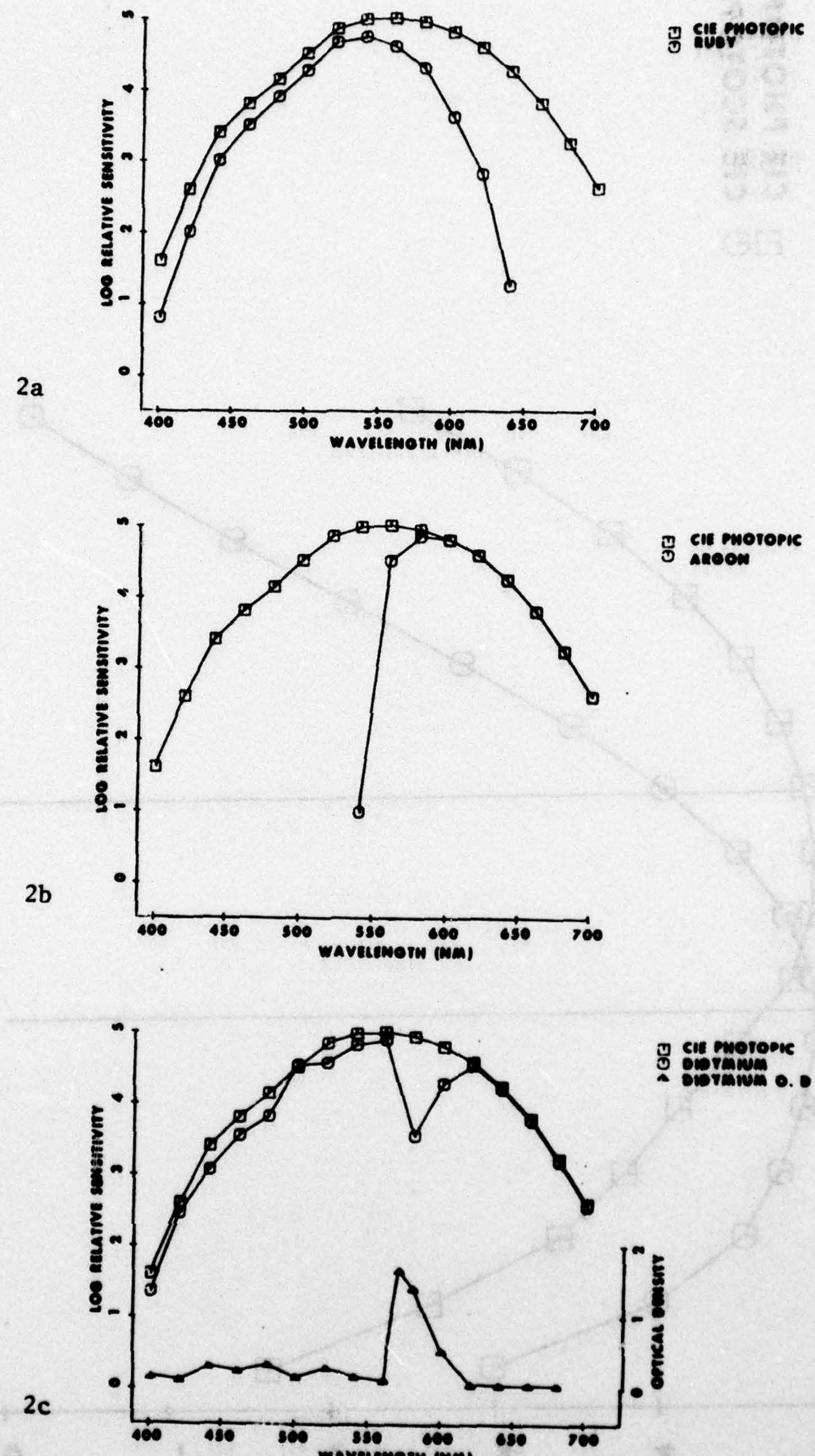
Figure 3 The effects of three combinations of two filter materials on the sensitivity of the CIE photopic observer are shown. The most effective protective combination is the didymium filter plus the argon laser protective material, although this combination severely restricts visibility in the region below 540 nm.

FIGURE 1



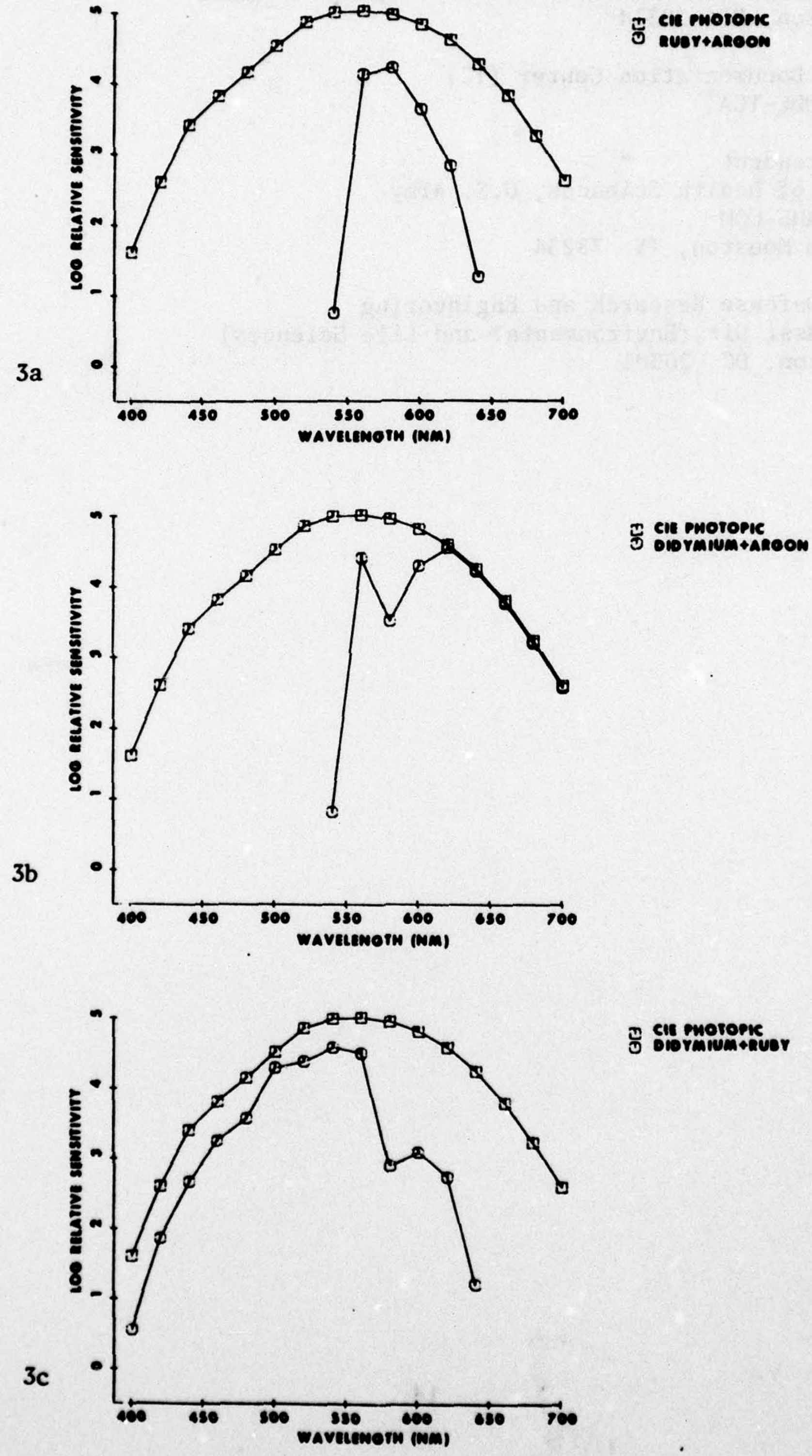
CIE PHOTOPIC
CIE SCOTOPIC
LOG RELATIVE SENSITIVITY
0
1
2
3
4
5
510
578
400
450
500
550
600
650
700
WAVELENGTH (NM)

FIGURE 2



LOG RELATIVE SENSITIVITY
WAVELENGTH (NM)
CIE PHOTOPIC
RUBY
2a
LOG RELATIVE SENSITIVITY
WAVELENGTH (NM)
CIE PHOTOPIC
ARGON
2b
LOG RELATIVE SENSITIVITY
OPTICAL DENSITY
WAVELENGTH (NM)
CIE PHOTOPIC
DIDYMIUM
DIDYMIUM O. D
2c

FIGURE 3


3a
LOG RELATIVE SENSITIVITY
WAVELENGTH (NM)
CIE PHOTOPIC
RUBY+ARGON
3b
LOG RELATIVE SENSITIVITY
WAVELENGTH (NM)
CIE PHOTOPIC
DIDYMIUM+ARGON
3c
LOG RELATIVE SENSITIVITY
WAVELENGTH (NM)
CIE PHOTOPIC
DIDYMIUM+RUBY
400
450
500
550
600
650
700
0
1
2
3
4
5

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